The Probabilistic Nature of Extended-Range Predictions of Tropical Cyclone Activity and Tracks as a Factor in Forecasts of Tropical-Extratropical Interactions

Patrick A. Harr
Department of Meteorology
Naval Postgraduate School
Monterey, CA
phone: (831) 656-3787 fax: (831) 656-3071 email: paharr@nps.edu

Award Number: N0001413WX20832

LONG-TERM GOALS

The overall project goal is to assess the skill of the probabilistic nature of medium- and extended-range forecasts of tropical cyclone activity and track over the tropical WPAC. Skill is examined with respect to processes associated with forcing by various tropical circulation factors, which are hypothesized to be the largest contributor to low-frequency variation in tropical cyclone activity and track type. Then, the impact of tropical cyclone activity on the medium- and extended-range forecasts over midlatitude regions downstream of recurving tropical cyclones is examined. For this objective, it is hypothesized that the interaction of the tropical cyclone outflow with the midlatitude circulation impacts the potential for downstream blocking and potential development of high-impact weather.

OBJECTIVES

A primary objective of this project is to examine medium- and extended-range predictions of tropical cyclone activity and track in a probabilistic framework. Accuracy of these predictions are assessed relative to low-frequency tropical forcing as primary controls on variability of tropical cyclone activity over extended range and intraseasonal scales. This secondary objective is defined to assess the amount of variability in general predictive skill of tropical cyclone activity and track that is explained by the Madden-Julian Oscillattion as a forcing of enhanced or reduced activity. The hypothesis that is examined is that skill of medium- and extended-range forecasts of tropical cyclone formation and track is increased when the large-scale conditions associated with the MJO favor tropical cyclone activity. Finally, the predicted tropical cyclone activity at medium and extended ranges are examined relative to predictions at similar time scales of midlatitude circulations that occur downstream. The hypothesis related to this objective is that accurate extended-range forecasts of tropical cyclone track characteristics will impact the predictions of downstream circulations that may initiate high-impact weather events (e.g., blocking, cyclogenesis).

APPROACH

To examine the hypothesis that medium- and extended-range prediction of tropical cyclone activity is increased during periods when the large-scale forcing of tropical cyclone activity is favorable over such temporal scales, periods in which tropical cyclone activity is favored or reduced are identified. In

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
30 SEP 2013		**00-00-2013 to 00-00-2013**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
The Probabilistic Nature of Extended-Range Predictions of Tropical Cyclone Activity and Tracks as a Factor in Forecasts of Tropical-Extratropical Interactions	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Postgraduate School,Department of Meteorology,Monterey,CA,93943**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**5**	

this context, a temporal cluster is defined as a temporally bound group of tropical cyclone occurrences of sufficient size and concentration to be unlikely to have occurred by chance. Furthermore, the cluster of tropical cyclone activity is defined such that the individual occurrences in the cluster are related through a common physical mechanism (i.e., the MJO).

To assess and convey the skill in extended-range forecasts of tropical cyclone activity, a series of three analyses are applied to:

- Analyze and convey the probabilistic character associated with forecasts of individual tropical cyclones within the framework of an ensemble prediction system;
- Examine a vortex climatology that defines the overall ability of an ensemble prediction system to produce reliable probability distributions of vortex numbers and characteristics; and,
- Define and analyze the utility of a super ensemble constructed through combinations of successive model integrations.

This three-pronged methodologyis motivated by the common practice of creating consensus forecasts and a requirement to introduce only gradual changes to long-term forecast strategies.

Archambault et al. (2012) found that the modification of the midlatitude circulation by the recurvature and extratropical transition (ET) of tropical cyclones over the WPAC is sensitive to the strength of the interaction between the tropical cyclone and the midlatitude flow into which it is moving. In extreme instances, a persistent, quasi-stationary upper-level anticyclone (i.e., block) may develop following an ET event. Understanding the precursors to blocking is a major forecasting concern because the associated anomalous large-scale flow pattern tends to favor a variety of high-impact weather events, including flooding rains, heat waves, and cold-air outbreaks. The key dynamical processes that link transitioning tropical cyclones to blocking and a high-impact weather event are based on the influence of tropical cyclone outflow on the strength and position of the North Pacific jet stream as a forcing of Rossby wave-like features that extend downstream (Fig. 1):

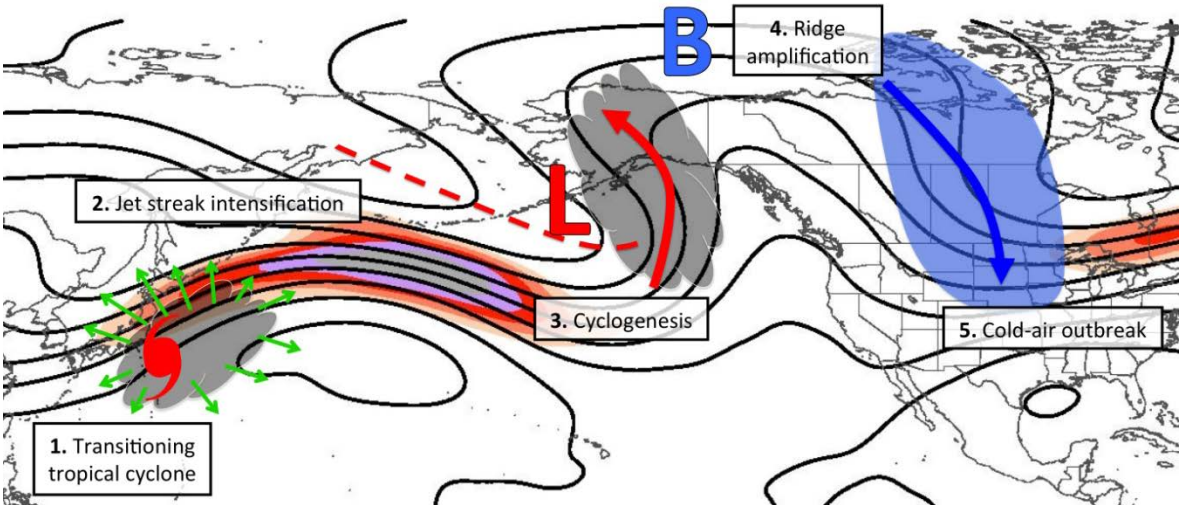

Fig. 1. Schematic depiction of the physical processes associated with the influence of ET events over the western North Pacific as precursors to downstream blocking episodes and high-impact weather events over North America. The factors described in each box define the evolution of the primary physical characteristics associated with the tropical cyclone-extratropical flow interaction.

A statistical analysis of the frequency of North American blocking episodes following western North Pacific ET events, and, conversely, the frequency of western North Pacific extratropical transition events associated with North American blocking is conducted. Additionally, how the statistical and dynamical relationships between western North Pacific ET events and blocking episodes vary depending on the phase of the MJO is examined.

WORK COMPLETED

An initial analysis of the temporal clustering of tropical cyclone activity over the western North Pacific has been conducted. Ensemble and deterministic extended-range predictions of synoptic-scale fields from the National Centers for Environmental Prediction Global Ensemble Forecast System (NCEP/GEFS) Reforecast-2 have been used to examine predictability in forecasts over the Northern Hemisphere midlatitudes. The once-daily (at 0000 UTC) Re-forecast-2 data are available from 1985 through the present and contain a deterministic forecast, control forecast and 10 perturbation members. This data set allows for a general examination of predictability because it is produced with a fixed model and uses re-analysis data for initial conditions.

RESULTS

During this initial year, effort has been concentrated on defining methods and data sets for analysis of predictabiliy and large-scale flow patterns related to tropical cyclone recurvature and ET. For example, tropical-extratropical interactions with respect to tropical cyclone outlfow has been placed into two classifications (Fig. 2).

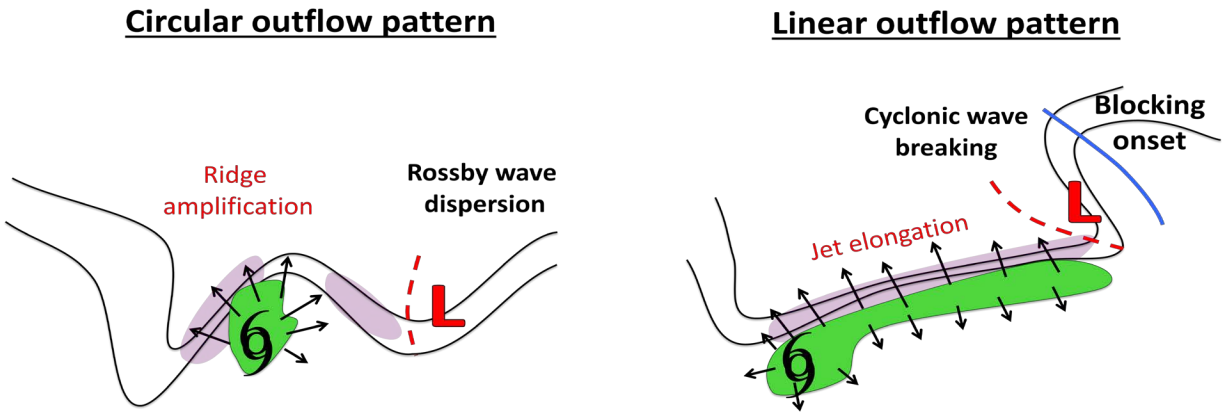

Fig. 2 Schematic of starburst (left) outflow and linear (right) outflow from a tropical cyclone to the midlatitude circulation.

Each outflow pattern has an influence on the character of the downstream midlatitude flow pattern that may be indicative of extreme cyclogenesis or the onset of blocking. Representative amplitudes and spatial patterns in predictability have been established in association with the two outflow patterns. Using the long period of forecasts provided in the reforecast data set, climatological values of predictability and uncertainty are computed. The forecast attributes associated with recurving tropical cyclones are statistically compared to climatological values to establish that recurving tropical cyclones are associated with periods of reduced predictability in downstream midlatitude weather

patterns. Furthermore, the tendency for predictability to be reduced relative to specific regions or flow patterns is examined.

A particular striking example of a linear outflow pattern and its impact on extreme cyclogenesis occurred in late September 2013 (Fig. 3). In this case, high-impact weather occurred over the Pacific northwest as the cyclone deepend rapidly in the Gulf of Alaska after the outflow provided an increased source of momentum and moisture into the developing parent cyclone.

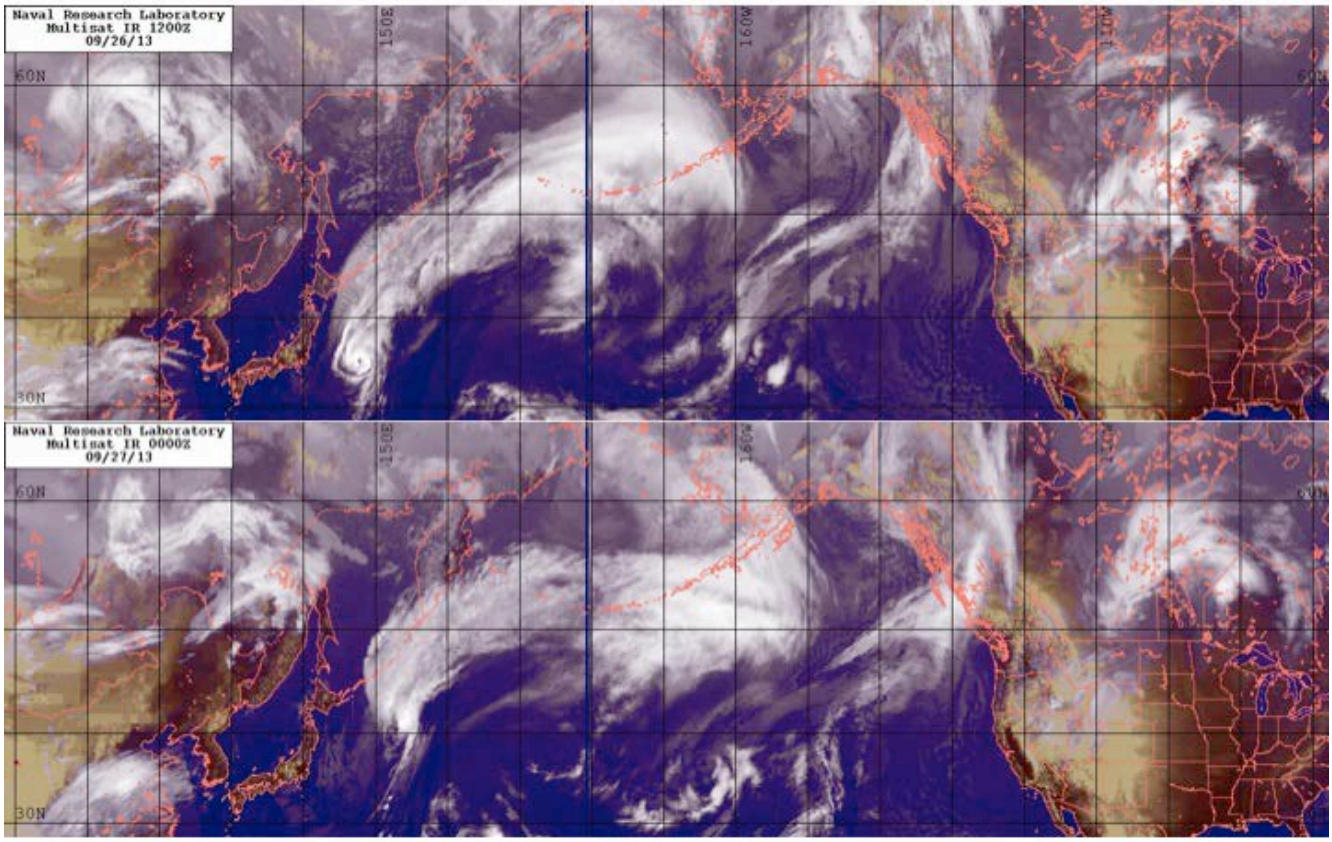

Fig. 3 Sitched geostationary infrared imagery for 1200 UTC 26 September (top) and 0000 UTC 27 Septemer (bottom). Typhoon Pabuk is located east of Japan with a large outflow plume of momentum and moisture extending into the rapidly-developing cyclone east of Kamchatka.

Based on the temporal cluster methodology and MJO classifications, a sample of 26 years was examined for significant clustering in the 30-60 day period and MJO classification. Eight of the 26 years contained significant temporal clustering of tropical cyclone activity over the period range of 30-60 days. Five (three) of the eight years with temporal clusters were (not) MJO years. Furthermore, five of the ten MJO years did not contain significant temporal clustering. These initial results are being analyzed for further statistical significance and interpretation.

IMPACT/APPLICATIONS

Results from this project are expected to define a coherent evolution of tropical-extratropical exchange that explains a portion of the variability in skill of extended-range forecasts. It is expected that these results will lead to increased understanding of the interactions between a tropical cyclone and its

environment that lead to high-impact atmospheric and oceanic conditions over the North Pacific Ocean.

TRANSITIONS

As this project is in its initial year, no transitions have occurred at this time. However, significant transitions are anticipated as a result of the statistical analysis and application to medium- and extended-range forecast products.

RELATED PROJECTS

The relationships among tropical cyclone structure and intensity changes to upper-level outflow is being examined in the project titled Tropical Cyclone Intensity and Structure Changes in relation to Tropical Cyclone Outflow (N0001413AF00002).

PUBLICATIONS

None during this first year.